EXECUTIVE SUMMARY

Sodium Bearing Waste (SBW) disposition is one of the State of Idaho's top priorities at the INEEL. The SBW technology roadmap has been laid out to capture for the first time exactly what development work must occur to resolve the key uncertainties in SBW disposition. The roadmap details the development activities for three alternatives that have performed well in contractor and department pre-decisional analyses: Cesium Ion Exchange, Solvent Extraction, and Direct Vitrification. The NEPA process will determine exactly which solution path will be followed, and the roadmap will be modified or adjusted to respond to that decision.

The roadmap schedule was developed based on a prioritization of uncertainties and the development activities they require for resolution. Where possible, activities that will resolve high impact uncertainties have been scheduled in the pre-conceptual design phase to effect the greatest risk reduction. The overall reduction in uncertainty for the various alternatives is captured in the risk waterfall, which can be used both to predict important milestones in the development program as well to track the results of the ongoing work and compare to the baseline. With this tool, the roadmap will help management to focus attention on any important issues quickly, limit unwanted schedule slips to a minimum, and provide guidance to risk associated with priority.

This roadmap, through the combined input of the High Level Waste Program, Engineering, Applied Technology, and Operations, has eliminated many of the disconnects in the program. Failure modes, safety issues, engineering needs, and their associated milestones have been validated. Each development activity has been scoped to meet requirements that fulfill one or more of these needs and issues. The roadmap schedule contains each of these important milestones and shows how the development program can produce the necessary results. Careful implementation of this roadmap should lead to success in the disposition of the SBW by December 31, 2012.

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1.0 INTRODUCTION

Early in the Fiscal year 2000, the Department of Energy Idaho Operations Office (DOE-ID) and Bechtel BWXT Idaho LLC (BBWI) management identified the need to develop technology roadmaps for technologies applied to the disposition of waste at the Idaho National Engineering and Environmental Laboratory (INEEL). The first roadmap assigned for development related to the disposition of the Sodium Bearing Waste (SBW) found at the Idaho Nuclear Technology & Engineering Center (INTEC) Tank Farm, the State of Idaho's number one priority at the INEEL.

Figure 1 shows the process by which this roadmap was developed and provides an outline of the sections of this report.

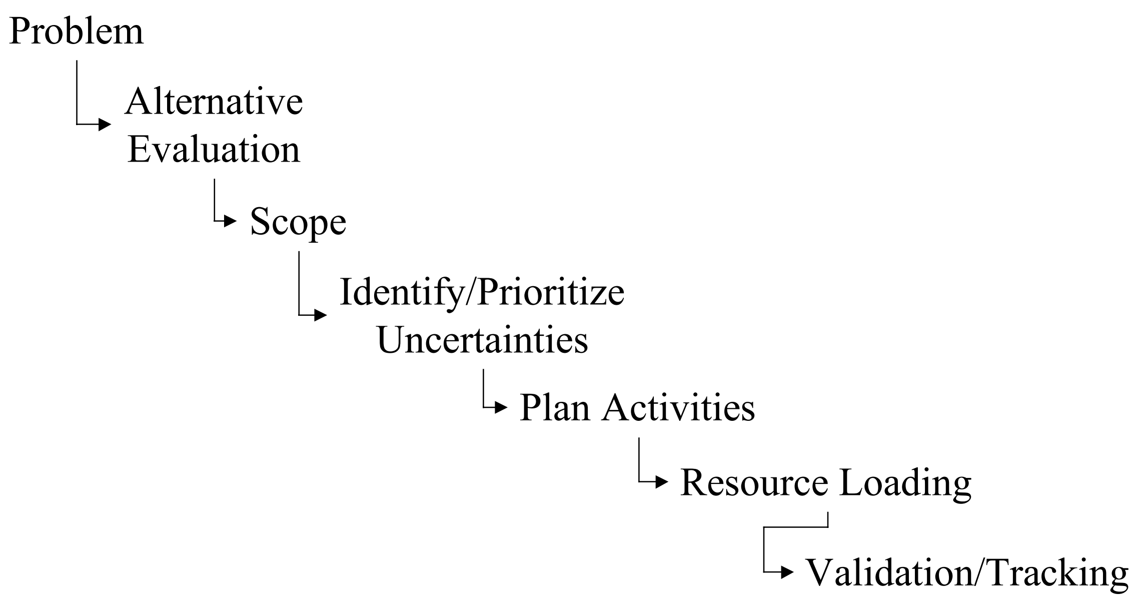

Figure 1. Roadmapping Process Diagram

1.1 Roadmap System Boundary

The SBW falls under the purview of the INEEL's High Level Waste (HLW) program. Although there are other aspects of the HLW program that will likely require technology insertion, management determined that this roadmapping activity would comprise only the technologies necessary to disposition the SBW, but the opportunity for integration of technology development for this and other ends were not ignored.

1.2 Drivers

The main driver for the decision and the roadmapping of the SBW technologies is the Settlement Agreement made with the State of Idaho. That agreement currently stipulates that the SBW in the Tank Farm will be removed from the tanks by no later than December 31, 2012. The technology development plan has been developed with this date in mind and endeavors to deliver the appropriate disposition technologies to allow for the engineering, construction, and operational phases of the program to take place by December 31, 2012.

The application of the technology roadmapping to the SBW issue is also driven at least in some part by technology development issues in DOE's past. This is not the first technical development program in the DOE complex and lessons learned indicate that the clear understanding of technology risks and mitigation of those risks that roadmapping provides is a key element in the successful planning and development of disposition technology. This roadmap is a normalization process driven by the disconnect to assure that the HLW program understands exactly what needs to be done, who will do it, and when it will be complete. This roadmap has revealed this complete information for the first time in the HLW program.

1.3 Problem Statement

The primary and most obvious driver in the development of technology is to avoid the consequences of uncertainties in that technology. Two kinds of uncertainties are focused upon in this roadmap, viability issues and engineering needs. If a viability issue is not resolved and ends up impacting a technology, the consequence would be the selection of a technology that cannot perform the required task and a loss of all the money and time invested in that alternative. For this program, the additional weight of the Settlement Agreement exacerbates this consequence significantly. Engineering needs that are not resolved may result in a high cost workaround or a non-optimal condition, but the process would eventually accomplish its goal. This level of consequence is not acceptable to the program and must be resolved. Prior to this roadmapping activity, it was not clear if or when all of these issues would be addressed. The roadmap solidifies the relationship between the development activities, viability issues, engineering needs, and development requirements for the first time in the HLW program.

2.0 ALTERNATIVES EVALUATION

In December 1999, DOE-ID assigned BBWI to evaluate and recommend a Liquid Waste Processing alternative for consideration in the Idaho High-Level Waste and Facilities Disposition Environmental Impact Statement (EIS) Record of Decision (ROD). DOE-ID also chartered BBWI to "roadmap" the technical development activities that would be necessary to support the delivery of the chosen technology(ies) for timely disposition of the SBW.

2.1 BBWI Recommendation

BBWI delivered the evaluation and recommendation to DOE-ID on March 15, 2000 to support the analysis taking place as part of the EIS ROD process. BBWI conducted their analysis from December 1999 through March of 2000 by gathering a group of Subject Matter Experts (SMEs) in the company to evaluate the available technologies bounded by the EIS.

The technologies evaluated based on the EIS can be divided into five main categories: Calcination, Ion Exchange, Separations, Direct Immobilization, and Hybrid Alternatives. Table 1 shows the nine alternatives that were analyzed and to which category they belong.

Table 1. BBWI Alternatives Categories

Calcination	Ion Exchange	Separations	Direct Immobilization	Hybrid Alternatives
Risk-based Calcination	Cesium Ion Exchange (CsIX)	Transuranic (TRU) Solvent Extraction (TRUEX)	Direct Vitrification	CsIX + TRUEX
Calcination with Maximum Achievable Control Technology (MACT) Upgrade		Universal Solvent Extraction (UNEX)		MACT Upgrade Calcination with direct shipment to Waste Isolation Pilot Plant (MACT to WIPP)
		Modified-UNEX		

The BBWI analysis resulted in recommendation of a dual-path solution: Calcination (either Risk-based or MACT to WIPP) and CsIX. The dual path was recommended for two main reasons. First, the analysis was based upon a certain precision of data that did not allow for a clear discrimination between first place (CsIX), second place (Risk-based Calcination), and third place (MACT to WIPP). Secondly, the remaining technological and programmatic uncertainties associated with CsIX and Calciner alternatives were not below a threshold of comfort that would allow for a single path solution. Therefore, a dual, risk-reducing path was recommended.

The basis for ranking the alternatives consisted in requirements and criteria that were used to measure the effectiveness of the various alternatives. In all, 14 criteria were measured and found to discriminate among the various alternatives. The data used to substantiate these results were documented in detail in the analysis report (see Appendix A, Reference 1).

2.2 EIS ROD Analysis

Since the EIS ROD is still in process in connection with DOE-ID following the policies laid out in the National Environmental Policy Act, no decision regarding the SBW disposition methodology has been made. However, since time is of the essence, the roadmapping process has continued in parallel with the NEPA process so that when a decision is reached regarding SBW disposition, the HLW program will be prepared to carry out the activities laid out in that decision.

DOE-ID and BBWI have been working to put themselves in a best position to react to the NEPA process. DOE-ID received the BBWI recommendation on SBW processing and incorporated the supporting data into its analysis portion of the EIS ROD process. As the analyses of BBWI and DOE-ID were independent, DOE-ID used different criteria and correspondingly different criteria weighting than the BBWI analysis. However, much of the support data were the same, and the different conclusions reached by DOE relate to decisions made by DOE concerning the likelihood and consequence of negative impacts due to technical and programmatic uncertainties.

Although the ROD process is still ongoing, there are three most probable solutions including CsIX, Solvent Extraction (either TRUEX or UNEX depending on the results of technical development), and recently Direct Vitrification. DOE-ID has instructed BBWI to roadmap these three technologies as a triple-path. As with the BBWI recommendation, the high probability that one of these will be the ROD's choice is the result of both high performers still possessing viability risks and a third path that is robust in technical and programmatic uncertainty although high in cost (Direct Vitrification). This ensures one alternative can be successful in meeting requirements and goals of the SBW treatment program hopefully by the 2012 deadline.

This roadmap, therefore, will plan in long-term detail for the development of the CsIX and Solvent Extraction processes. As the Direct Vitrification is a recent addition to this roadmapping process, a detailed pre-Conceptual Design plan will be included in the roadmap with further evaluation at the next major decision point (see section 3.1 Key Decision Points). In any case, the ROD will determine the final path forward and all parties will work together to realize the potential of the chosen process.

3.0 SCOPING METHODOLOGY OF THE ROADMAP

In addition to understanding the scope of the roadmap, which began with the discussion of the system boundary and ends with the above explanation of the triple-path approach to solution, the methodology for scoping the elements and activities in the roadmap is important.

3.1 Key Decision Points

As stated, one of the drivers of the roadmap is the desire on the part of the INEEL to meet the agreements with the State of Idaho laid out in the Settlement Agreement. The key aspect of the Settlement Agreement relative to the SBW processing is the requirement that the SBW shall be removed from its tanks by December 31, 2012. Working backwards from that date, project management tools can be used to show when the several phases of the processing projects must begin: operations, construction, title design, and conceptual design in reverse order. Laying these elements out, with experience and data providing the durations of each, yields key decision points for each alternative.

Figure 2 graphically depicts the key decision points for the triple-path solution. (Referring back to Section 2.2, it is critical to point out that these dates do not correspond to the ROD but rather are critical dates based on the December 2012 milestone. The ROD will provide the final decision on the subject of SBW processing.) On June 1st, the finalists from the analysis will be revisited to determine the best path forward based upon available development data at that point. If any technical or programmatic viability issues are identified for a given alternative, that alternative will be discontinued. If viability issues are still possible, then a dual path is necessary to decision point 3.

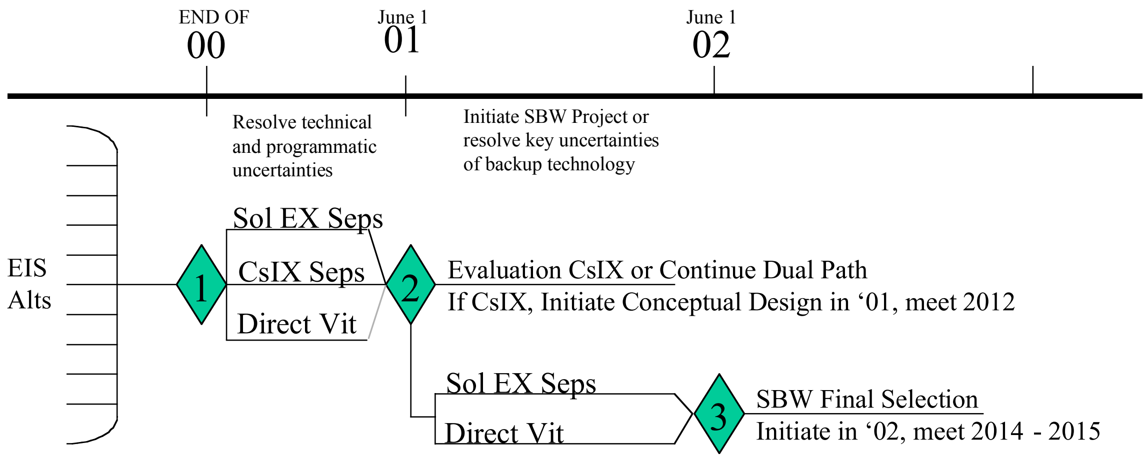

Figure 2. Decision Points in the SBW Roadmap

The key driver in meeting the requirements of these decision points is the reduction of uncertainty. In order to make these important decisions in a timely manner, technical development (in this case the HLW Applied Technology department) will provide recommendations to engineering based on demonstration of viability of key aspects of the technologies. These aspects are related directly to the uncertainties existing in the processes and their associated consequences. It is therefore very important in the roadmapping process to understand the uncertainties of the solution alternatives.

3.2 Uncertainty Definition

Defining the uncertainties of a process proves to be a very important and very difficult phase of roadmapping. The difficulties lie in inherently biased experts using objective methods to unearth the issues and problems for various technologies, as well as setting the rules for the objective methodology. The SBW analysis performed several iterations on this subject, eventually arriving at an objective, repeatable, and useful system for discovering technical uncertainties.

The uncertainties used in this roadmapping process can be categorized in many ways. The first categorization that was used in the development of the uncertainty list was failure modes, safety issues, and engineering needs. The technologists took several days and brainstormed as many failure modes and safety issues (see Appendix B.1, Failure Modes and Safety Issues) as they could for each other's technologies. Engineering representatives, both in house and from subcontractors to be used in the design process, presented their desire for understanding certain aspects of the technology that they deemed as yet inadequately defined (see Appendix B.2, Engineering Needs). Upon compiling these three lists, the technologists and engineers then tried to understand the existing knowledge base for each uncertainty.

The team performing the SBW analysis decided it was important to break these uncertainties up into high, medium, and low categories. The method for dividing up the uncertainties was to determine the available knowledge on the subject. That is to say if an uncertainty had no known data so support an engineering solution, it was listed as a high uncertainty. This does not necessarily indicate a level of difficulty of solving the problem; rather there is no known data to validate the assumption being used. If there were data describing evidence of an engineering solution, but there was limited example of implementation of the solution, it was listed as a medium uncertainty. Finally, if there was evidence of both an engineering solution and several examples, complex-wide of successful implementation of the solution, the uncertainty was low.

Later, as the team focused more on the potential consequence of these uncertainties, it was determined that the list could be categorized based on consequence rather than knowledge base. The uncertainties were then divided by whether their failure could impact the viability of the process, result in high cost impacts (e.g. footprint changes), or impact the optimization of the process. Many of the uncertainties that were listed in the high category based on knowledge base also found themselves in the viability area based on consequence, but the correlation was not 100 percent. This last categorization method turned out to be the most fruitful with respect to laying out the development activities in the roadmap.

4.0 ROADMAP DEVELOPMENT STEPS

Where the majority of the activities above were completed as part of the SBW analysis, the steps detailed below developed and aligned the data into a roadmap format for future use by the technology development program.

4.1 Connecting Activities to Needs

The kickoff to the roadmapping phase of the process occurred during an alignment of needs and development activities. Up to this point, the technology development program had laid out a reasonable list of activities needed to meet the requests of engineering for resolution of unknowns. The SBW analysis did unearth some other uncertainties in the processes as well as timing disconnects between development and engineering that required address. The roadmapping team gathered together to link up the planned development activities with the uncertainties. The team found that many of the uncertainties lined up well with the scope of the development activities. Some activities required small changes in scope to include the gathering of the desired information to resolve a given unknown. Few of the unknowns had no specific development activity ready to address them; for these new activities were scoped out to meet the need.

In addition to this alignment of activities and needs, the requirements for each activity were solidified. Prior to roadmapping, it was understood that a group of activities would solve a group of needs, but it was unclear as to which specific activity solved which specific need or provided what piece of data to another activity. Making these connections identified exactly what deliverables were required of a given activity, and this helped solidify the requirements of the activity, both in work scope and schedule. The roadmapping identified exactly what development needs to do and when they need to do it.

Figure 3 shows an example of the database used to understand the connections between development activities and uncertainties. It was created in a system called Graphical Modeling System (GMS). GMS is a graphical depiction of a Microsoft Access database. The example shows an uncertainty from the Solid Liquid Separations (SLS) unit operation in the CsIX alternative. The uncertainties were laid out by unit operation to facilitate connection to the development activities that were similarly organized.

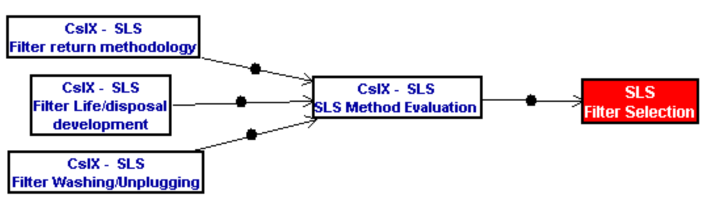

Figure 3. Activity – uncertainty relationship.

To explain this example, the key activity here is the SLS method evaluation. This is one engineering need that will drive the selection of a filter type, which is necessary prior to the beginning of conceptual design (as witnessed by the red coloring). There are three activities that provide data to that evaluation: filter return methodology (or how to return the solids captured by the filter to the waste holding area), filter life/disposal development (or how to maximize the life and then properly dispose of the filter), and filter washing/unplugging.

This alignment of activities and uncertainties assisted in both defining the full scope of development activities needed to resolve all uncertainties and in providing the foundation for laying out the schedule necessary to reach timely delivery of these solutions. Figure 4 provides and example of how the GMS information in figure 3 would translate into schedule information in Microsoft Project, which was used to lay out the schedule of activities. Note that the three pieces of information used to drive the method evaluation are lumped in the activity of "evaluate/consolidate existing data".

⊟ **SLS**	**195.4 wks**	**09/04/00**	**06/01/04**
Small Demo on SpinTech	4 wks	09/04/00	09/29/00
Preliminary Feed Specs for IX	3 wks	09/04/00	09/22/00
Evaluate/Consolidate Existing Data	6 wks	09/25/00	11/03/00
SLS Method/Technology Evaluation	8 wks	11/06/00	12/29/00

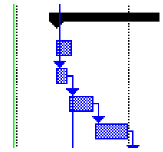

Figure 4. Schedule translation of database information.

Once input to the scheduling program through the use of macros, the activities could then be prioritized.

4.2 Prioritization of Activity by Uncertainty Impact

Leveraging the categorization of needs by their impact on viability, cost, and optimization, the team was able to prioritize development activities by impact. A well-defined development program should endeavor to reduce as much risk as possible early in the program, leaving time in design for small optimizations or "tweaks" to the process.

As stated above, the technologists were asked to assign levels of impact for each of their development activities relative to which need(s) the activity would address. By normalizing these inputs, it became clear which activities would cover viability, high cost, and optimization uncertainties. Those activities were then laid out in a schedule in order of decreasing impact when possible. In some limited cases, the logic of activities, i.e. the need for certain activities to be preceded by other less impact-full activities, required that some higher impact activities come later in the development cycle. This methodology allowed for a defensible layout of the schedule basis of the roadmap. The schedule portion of the roadmap for the activities common to all alternatives (e.g. Characterization) is found in Appendix C.1, the CsIX alternative is found in Appendix C.2, the Solvent Extraction portion in Appendix C.3, and the near term Direct Vitrification activities in Appendix C.4.

4.3 Detailed Planning

The roadmap provides the ideal starting point for the Detailed Work Planning (DWP) process. BBWI management requires DWP for the input and tracking of any project activities. The detailed planning goes to the next level of activity. For these technical development activities, the main tasks listed in the roadmap are broken up into various subtasks necessary for any technical development activity. Table 2 shows a template that was used for each roadmap level activity to input resources and durations at the DWP level.

The DWP resource entries are then plugged back into the roadmap after having been rolled up to the roadmap level. This provides necessary planning information from the point of view of resource needs and budget requirements. Cost profiles and resource utilization analyses will be used by the Applied Technology program to plan for additional funding and resource needs. Although not available at this time due to the status of the DWP process, the cost and resource profiles will be appended to the final roadmap delivered by fiscal year's end.

	Hours				Dollars			Weeks
Task	Exempt	NonExempt	Analytical	Other	Materials	Subcont	Travel	Time Req'rd
Approach Dev								
Run Plan Prep/Review								
Procurement								
Set-Up Time								
Perform Tests								
Analytical /data receipt								
Data analyses								
Report prep/publish								
ISM, training, meeting, misc.								
Projects support/interface								
Activity Total								

Table 2. Template for DWP entries.

4.4 Validation

Any solidly engineered device, system, or process requires validation. It is necessary to show both the value of this roadmapping effort and that it has spawned a useful and executable plan. The aforementioned cost and resource utilization profiles will help determine if the plan is executable, but a new approach has been used to validate the utility of the roadmap.

The roadmap endeavored to time-phase the risk reduction in the development process to be front end loaded. A risk waterfall diagram would show if the roadmap indeed succeeded in this effort. A risk waterfall diagram shows a plot of existing or planned levels of uncertainty over time. Figure 5 shows the risk waterfall curves for CsIX and Solvent Extraction. As the out-year scope for Direct Vitrification is solidified, it will also be included in the figure.

The figure contains risk waterfall curves for three separate alternatives created from fictional data. These curves show the reduction in *uncertainty* rather than the reduction in baseline cost. These reductions in uncertainty may result in rising project cost, but the key is that the uncertainty is reduced and therefore the project cannot balloon by that amount later. History has shown a desire on the part of DOE upper-management to have a better handle on the baseline cost during technical development, and this type of chart would allow that.

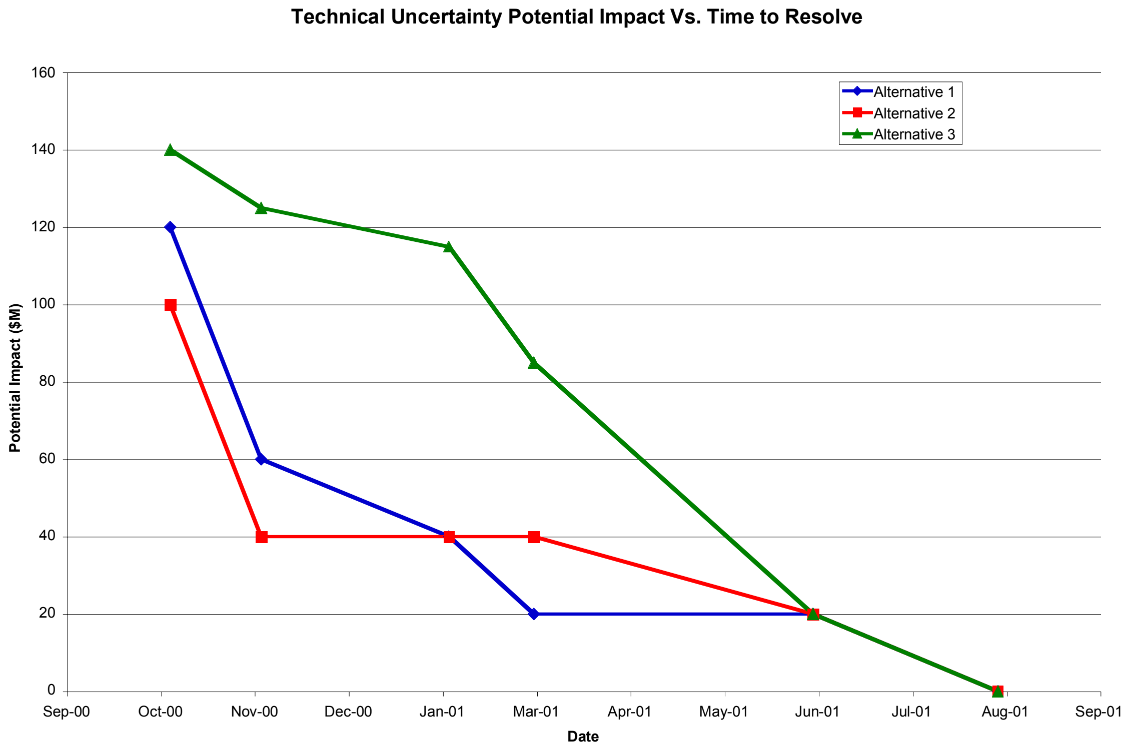

Figure 5. Sample Risk Waterfall chart.

Alternatives 1 and 2 show relatively favorable behavior in that their level of uncertainty reduces quickly in the early stages of the program and eventually falls to an immeasurable amount. Alternative 2 shows a small period between November of ’00 and March of ’01 where the uncertainty is not being reduced. This could result from several necessary predecessors being completed in anticipation of a final activity that solves a particular issue in March, resulting in the drop from that month through June of ’01. This may also be indicative of a lack of necessary testing going on in that period. In either case, the curve serves its purpose in that a development program manager would examine the tasks in this period closely to see if they were getting the most for their money.

Alternative 3, although steadily declining over time and eventually reaching near zero, shows a shape that is not optimal. For the same reasons as with Alternative 2 this shape may be necessary, but ideally the risk reduction in January ’01 through August ’01 period would be moved into the beginning of the program with the more shallow reductions following those efforts. This would yield a nearly optimum curve since the highest risk for the alternative would be eliminated early in the development program. With this understanding, the actual waterfall curves for CsIX and Solvent Extraction (Direct Vitrification will be included when the out-year scope is solidified) are available in Figure 6.

The risk waterfall tool aids the development program in several ways. First, the tool can be used to select alternatives by monitoring performance of the development activities relative to the baseline curves. If, as time goes on, an alternative’s level of uncertainty stays constant rather than following a downward progression shown in the baseline curve, this would indicate significant “discovery” in the alternative. Discovery is defined here as finding new unknowns

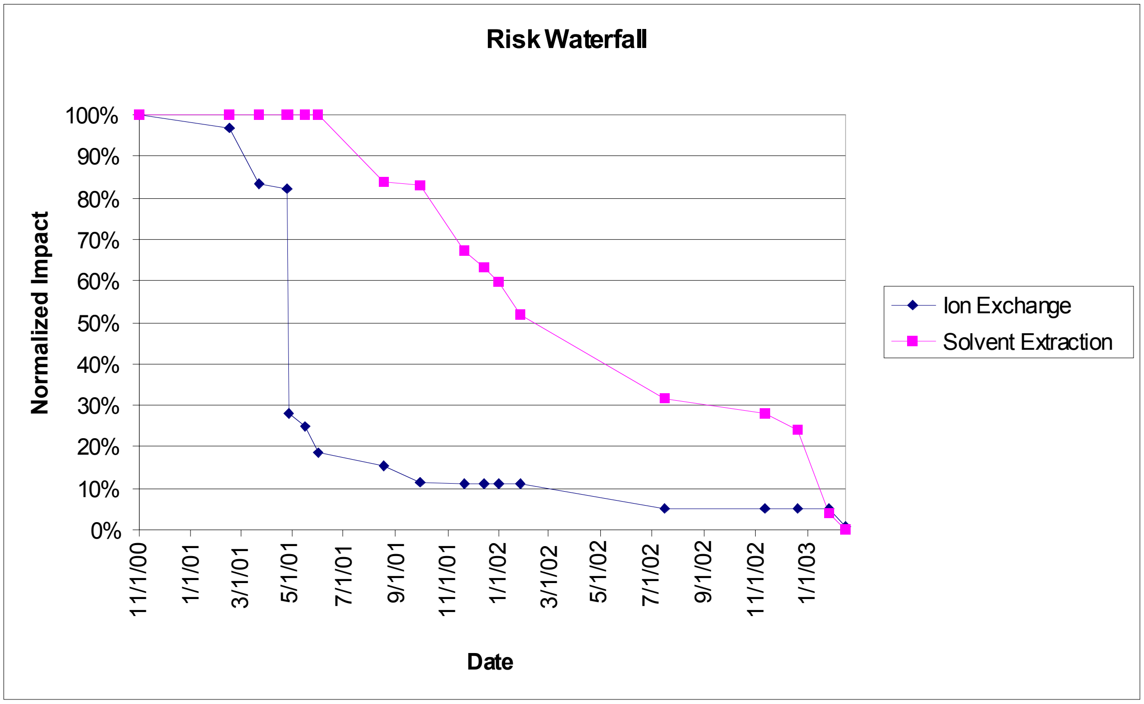

Figure 6. Risk Waterfall Diagram for CsIX and Solvent Extraction.

while developing a process that were not originally captured in the planning phase. The risk waterfall can only measure the uncertainty of the unknowns that the program is aware of at a given time, while experience has shown that some development programs discover additional unknowns over time, usually proportional to the immaturity of the technology. As a curve continues to stay at the same level of uncertainty, the alternative should be considered for elimination due to high rate of discovery.

When compared to key decision points, the risk waterfall curve would also give a good representation of the various levels of uncertainty predicted for the decision points. This would help managers see, at least in an early prediction, the remaining uncertainty at the point of decision and allow, in a flexible program, the potential to move decision points or attempt to accelerate progress. Indeed, DOE Headquarters often requests this kind of information when decisions are made relative to entering different phases of the design process.

The intent of the risk waterfall curve is to allow the development program manager to see the time phased reduction in uncertainty and make any possible changes to optimize that effort. If used correctly, this curve should be used to both plan activities in the early stages of a program and track progress throughout.

4.5 Tracking

The roadmap is not an end in itself rather a living document that helps the responsible parties make decisions with the best possible information at hand. Scheduling activities for maximum uncertainty reduction and planning resources effectively at the beginning of the program are only a part of this effort. As work is completed and results produced, the schedule and the uncertainty curves can be updated and compared to the baseline to observe trends in the program. As described above, a telling scenario would occur if an expected large reduction in uncertainty were postponed for one or more status points. This behavior has occurred in the past and has been a portent of greater difficulties to come. It is important to recognize this type of event as early as possible, and these tracking tools would help in that recognition.

By tracking the development program through the roadmap, the managers implement the most important and final phase of the roadmap, living by it. Roadmaps were created as a way to plan the steps toward innovation, a difficult concept in any setting. They require a common understanding of the overall goal and some vision on how to achieve it. The steps taken above have laid the foundation for success in the SBW program. Development and engineering are more in sync and there is a clear development plan with concrete requirements and deliverables for each activity. Achieving the results is now the responsibility of those in the development program who will implement the plan laid out here. Watchful implementation of this roadmap can lead to success in reaching the goal of disposition of the SBW the in the INTEC tank farm, the State of Idaho's number one priority at the INEEL.